Main outcomes from the PATRICIA program on clad to coolant heat transfer during RIAs

Vincent BESSIRON

Institut de Radioprotection et de Sûreté Nucléaire (IRSN)
Centre d'Etudes de Cadarache
13115 Saint Paul lez Durance BP3 FRANCE
Tel : 33 4 42 25 66 19
Fax : 33 4 42 25 61 43
E-mail : vincent.bessiron@irsn.fr

Abstract

In the frame of the studies on Reactivity Initiated Accidents (RIA), IRSN, with the support of EDF, has initiated an experimental program in order to investigate the clad-to-coolant heat transfer under fast transients.

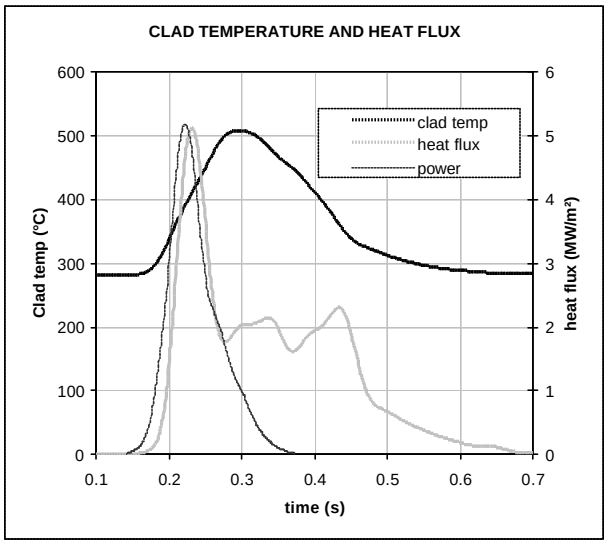
This program has been carried out in the PATRICIA loop of CEA, using single cladding tubes centered in an annular channel with radial dimensions representative of a PWR sub-channel. The clad is heated up by direct Joule effect and the transients are representative of the heating rate induced by the fuel during a neutronic pulse.

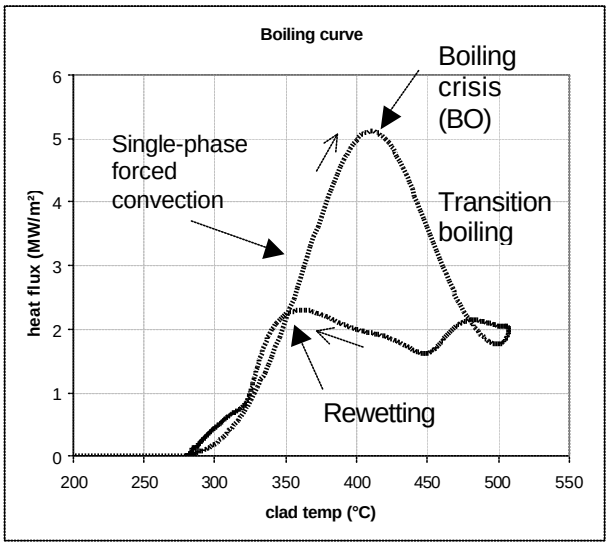
The clad-to-coolant heat-transfer is estimated by the measurement of the clad inner temperature and by the calculation of the temperature field within the clad thickness. The uncertainty range is ± 30°C on the clad outer temperature and ± 25% on the clad-to-coolant heat flux.

Both PWR conditions (150 bars, 280°C, 4 m/s) and NSRR conditions (atmospheric pressure, room temperature, stagnant water) have been simulated. Steady-state experiments which allow to make the link with the usual correlations have been performed too.

The experiments exhibiting boiling crisis are characterized by two main features that can be clearly seen on the boiling curve:

- presence of transition boiling: decrease of the flux with simultaneous increase of the clad temperature,
- presence of a rewetting peak.





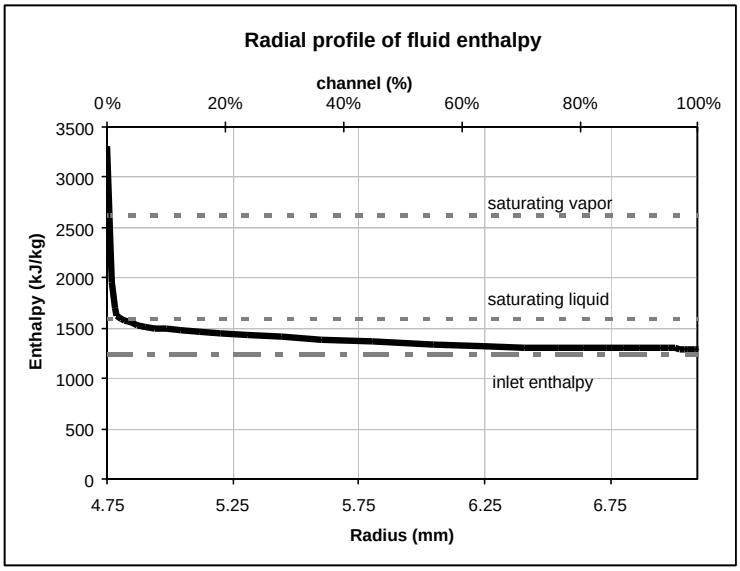
The physical interpretation of the experiments led to assert the main characteristics of the clad-to-coolant heat-transfer on bare rods in PWR conditions at 280°C under very fast transients which are:

- the boiling crisis is mainly governed by the flash boiling of a superheated liquid layer without sufficient time to get fully established nucleate boiling heat transfer,

- the critical heat-flux is of the order of 5-6 MW/m² reached around Tsat + 50°C (~Tsat+20°C in steady-state conditions),

- the fast crossing of transition boiling is followed by inverse annular film boiling with heat flux of the order of 1-2 MW/m².

Calculations with the TH2D computer code (two-phase and 2D code designed for computing thermal-hydraulics during a RIA and developed within an IRSN/Kurchatov Institute cooperation) allows to estimate the topology of the flow during the transient. The next figure shows that most of the coolant is not affected by the clad heating: the thermal gradient only concerns a small fluid layer in the vicinity of the wall. The vapor film reaches approximately 5% of the channel.



These results are intensively used for the development and the validation of the SCANAIR code and for the definition of the future CABRI tests in the Water Loop.